

CCD Scanning for the Discovery of Comets and Asteroids

T. Gehrels, R. Jedicke, R. S. McMillan, M. L. Perry, J.V. Scotti, T. Bressi
Space Science Building, University of Arizona, Tucson, Arizona 85721

CCD scanning was developed at the 0.9-meter Newtonian telescope of the Steward Observatory of the University of Arizona. Three CCD systems of increasing performance have been in operation since 1981. Presently, about 70,000 observations are made a year which includes astrometry for about 25 near-Earth asteroids. A new altitude-azimuth folded prime focus Spacewatch Telescope of 1.8-meter aperture is being built.

The general goal of our work is to obtain magnitude-frequency relations for various populations of small bodies in the solar system. The work is a sequel to photographic surveying of the solar system at the Yerkes, McDonald, Palomar and Leiden observatories, but it is now done with CCDs, charge-coupled devices (Gehrels 1991, Scotti 1994). The work is presently done at the 0.9-meter Spacewatch Telescope while a new 1.8-meter reflector is being built. During the bright part of each lunation, centered on full moon, the telescope is dedicated to the detection of planets of other stars (McMillan et al., 1994).

Spacewatch CCD Scanning

Before Spacewatch, the discovery of near-Earth asteroids was done with photographic cameras so slowly that it might have taken a century to find the 1,700 largest comets and asteroids that are dangerous to life on a global scale. In 1981 we set out to develop new techniques with electronic detectors and fast computers to increase the discovery rate. The new techniques were first developed on an existing 0.9-m telescope that the Steward Observatory had made available; we now call that the Spacewatch Telescope. The automatic detection required some eight man-years of computer programming. Three consecutive scans are made of the same strip of the sky; the moving objects are identified from comparison of the repeated scans. The instrumental developments have attracted wide attention as have our discoveries. During a clear winter night some 600 moving objects are found, which are mostly asteroids in the main belt between the orbits of Mars and Jupiter. On average, about one in 900 of such discoveries will yield an object that might come close to the Earth. The distance from the Sun is distinguished from the reflex of the Earth's motion, as is shown in Fig. 1, which works well in directions opposite to that of the Sun.

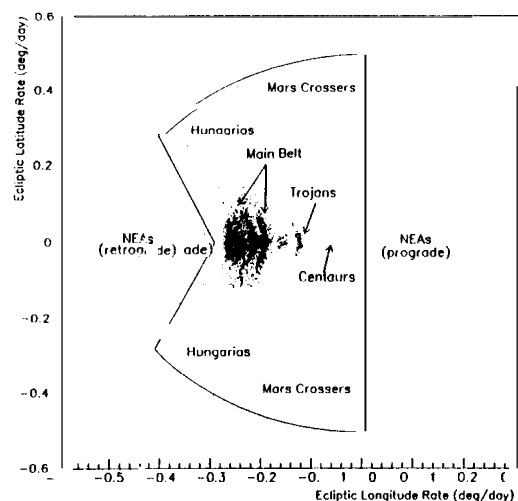


Figure 1. Plot of Ecliptic Latitude and Longitude Rates

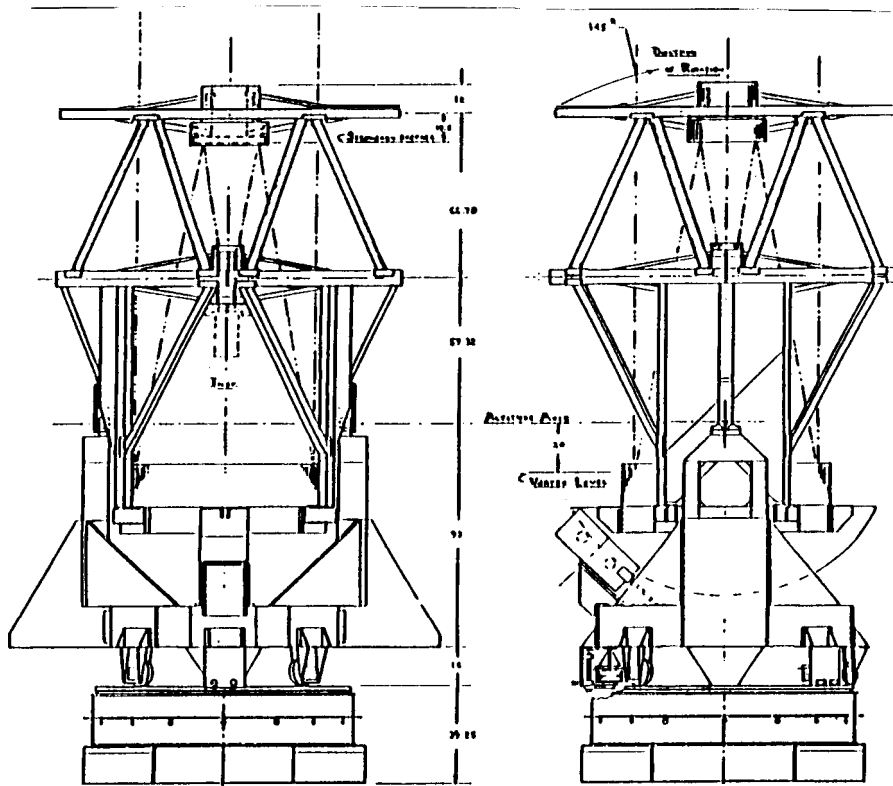


Figure 2. 8-m Folded Prime Focus Spacewatch Telescope

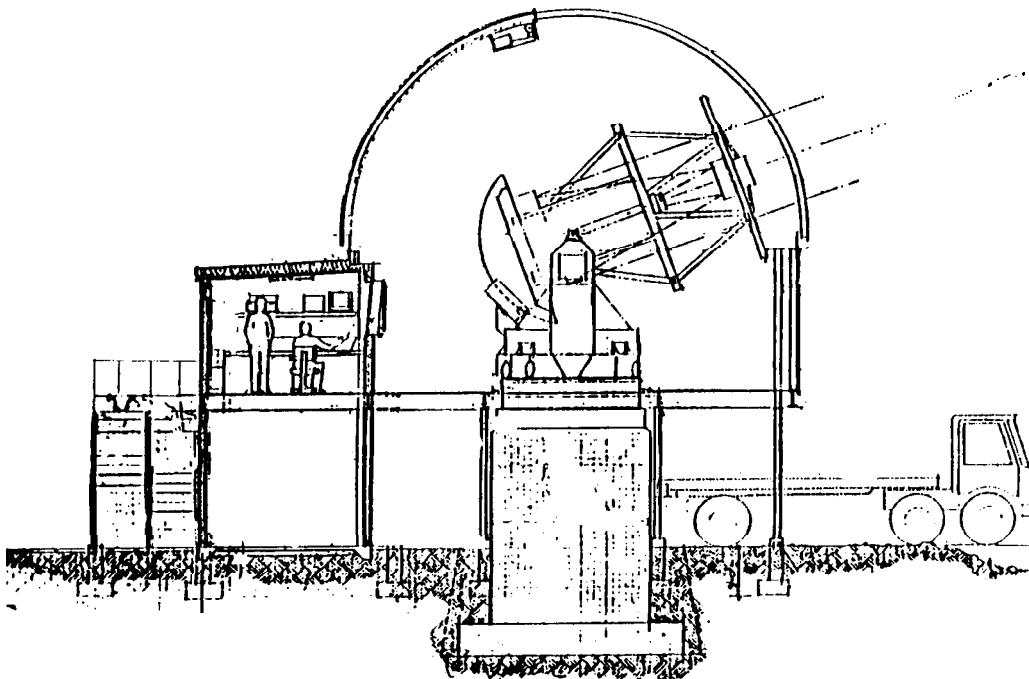


Figure 3. Pier, Dome and Building at Kitt Peak

Summary of Results

Spectacular discoveries have already been made. A grouping or family of small asteroids was found, of about 10-meters' size. The explanation of the phenomenon is keenly debated among colleagues. Another discovery is of large objects, 100 kilometers, in the outer solar system, near the orbits of Saturn, Uranus and Neptune. This population had been predicted, but farther out, near Neptune, as a source for comets and near-Earth objects eventually. A sample of findings is shown in Table 1.

The present rate of discovery of near-Earth asteroids is about 25 per year; it is still being improved. In 1994, about 70,000 astrometric positions were reported to the Minor Planet Center in Cambridge, Massachusetts. Our results have been reported and discussed in some 40 publications to date. The popular interest in this work is also considerable, with international TV reportages and articles by science writers in various journals.

Table 1. Examples of Discovered Objects

Identification	Perihelion distance (AU)	Aphelion distance (AU)	Diameter (km)
1992 AE	1.24	3.20	3.30
1994 XM1	0.90	3.10	0.01
1993 EA	0.53	2.00	2.10
1992 BA	1.25	1.40	0.40
1991 VG	0.97	1.10	0.008
P/Jedicke	3.80	7.80	-
1992 AD	8.70	32.20	140.00

1.8-m Spacewatch Telescope

The new telescope has a lightweight fused-silica mirror 1.8 meters in diameter. The telescope design is made by Larry Barr who has worked on large telescopes at the Kitt Peak, the Lick and Mauna Kea Observatories. The telescope (Figs. 2 and 3) is of a new design that we call a folded prime focus, which yields a short, compact tube, a sturdy instrument even in adverse weather conditions. The telescope is presently being built in the University Instrument Shop. This is an ideal situation in which the people who will have to run and maintain it are close to the fabrication. Students are attracted to this new program of sky surveillance. We are making a special facility, for generations to come.

References

- Gehrels, T. 1991, Scanning with Charge-Coupled Devices, *Space Sci. Rev.*, **58**, 347-375
Scotti, J. W. 1994, Computer Aided Near - Earth Asteroid Detection: A Spacewatch Perspective,
in *Asteroids, Comets, and Meteors* 1993, A. Milani et al. (eds.), 17-30
McMillan, R. S., Moore, T. L., Perry, M. L., and Smith, P. H., 1994, Long Accurate Time Series Measurements
of Radial Velocities of Solar-Type Stars, *Astrophys. & Spac. Sci.*, **212**, 217-280